



Grinding induced martensite on the surface of rails

Rasmussen, C.J.; Zhang, Xiaodan; Danielsen, Hilmar Kjartansson; Fæster, Søren

Published in:

Proceedings of the Risø International Symposium on Materials Science

Publication date:

2014

[Link back to DTU Orbit](#)

Citation (APA):

Rasmussen, C. J., Zhang, X., Danielsen, H. K., & Fæster, S. (2014). Grinding induced martensite on the surface of rails. *Proceedings of the Risø International Symposium on Materials Science*, 35, 439-446.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

GRINDING INDUCED MARTENSITE ON THE SURFACE OF RAILS

C.J. Rasmussen*, X. Zhang**, H.K. Danielsen** and S. Fæster**

*Banedanmark, Technical Operations & Maintenance, Track,
Vasbygade 10, DK - 2450 Copenhagen SV, Denmark

**Technical University of Denmark, Department of Wind Energy,
Section for Materials Science and Advanced Characterization, Risø
Campus, 4000 Roskilde

ABSTRACT

Rolling contact fatigue (RCF) is causing crack initiation and crack propagation in rails. Some types of RCF cracks are found to be associated with a white etching layer (WEL). A metallurgical investigation was carried out on a worn rail and the amounts of WEL at different positions on the rail were determined. Two different rail types R260 and R350HT that both had been ground by a grinding train were investigated. The rail sections, studied using optical and scanning electron microscopy, showed that the surface of both types of rails is covered with WELs. The hardness of the WEL is increased compared to the base material and the microstructural investigations reveal that a martensitic structure is present at the surface.

1. INTRODUCTION

In Denmark as well as most other countries in the world rolling contact fatigue (RCF) cracks initiated at the surface of rails have been a significantly growing problem - especially in the last two decades. The treatment of RCF is essential for the extent of maintenance, ensuring safety, lifetime and costs.

The initiation and the development of the different types of RCF cracks are depending on a wide range of parameters in a very complex combination. Some types of RCF cracks like squats have in many cases been found to be associated with a white etching layer (WEL) which is a heat affected layer on the surface of the rail that has turned the original pearlitic bulk material into a martensitic structure – see examples in Fig. 1.

environment; c) plastic deformation introduced fine microstructure (Griffiths 1987). But when the condition is restricted to the machining, grinding and deformation processes, additional factors such as pressure, strain rate and cooling rate, take effect. Specific pressures for metal grinding are of the order of $\sim 10^4$ MPa (Boothroyd 1975). High pressure may reduce the transformation temperature as the density of austenite is higher than ferrite. The order of reduction degree can be evaluated by an example (Darken and Gurry, 1953) that a pressure of 2.84 GPa reduced the transformation temperature by 180 °C. Rotation speed is another important factor which combines strain rate and cooling speed. A higher rotation speed generates more heat and a higher temperature, and high speed may also include the effect of strain rate by creating adiabatic shear bands on the micrometer scale at the surface. The increase of temperature with machining speed was evidenced in the case of hard-turning of AISI 52100 steel where the cutting speed of 30 m/minute increased the temperature to 550 °C, the improvement of speed to 260 m/minute increased the temperature to above 830 °C and in both cases WEL formed (Hosseini 2013). The high cooling speed accompanying machining and grinding is also a main reason for the formation of the complexed “mixture” of pearlite and martensite where the thin cementite lamellae retained in the WEL as shown in Fig. 5. This indicates that the need for complete dissolution of cementite was not satisfied in the combination of time and temperature where the cooling rate can be around 10^5 °C/s.

3.2 Retained austenite. Retained austenite is detrimental to components as it will transform to martensite during the following service and bring the volume change and stress concentration for the crack initiation and propagation. However, it is difficult to determine its content in the thin WEL and its effect on the service life of rails is also not clear for there is no direct correlation between the CRF cracks and WEL at present.

3.3 Residual stress. Residual stress is important for the initiation and propagation of RCF cracks. A compressive residual stress will suppress the cracks’ initiation and propagation while a tensile residual stress will assist. The 3D distribution of residual stresses is related to the grinding route and parameters. The existence of WEL will make the measurement of 3D residual stress more difficult especially in a two-phase microstructure with a nanoscale structure.

4. CONCLUSION AND OUTLOOK

Worn rails from a line with light weight passenger trains and ground but otherwise unused rails have been investigated by optical and electron microscopy.

The WELs on the worn rails from a Danish line with a relatively low traffic and with passenger trains were found to be martensite based on the microstructure observed with high resolution electron microscopy. The WELs were only found as small islands and generally with a layer thickness of less than 10 µm in the worn rails. The amount of WEL was determined to decrease with increasing contact between the train wheel and the rail – the more contact the less WEL.

The ground rails (R350HT head hardened and the normal R260) which were inspected before any trains have been running on the rails both have a martensitic layer covering the whole surface. The layer thickness is typically less than 10µm and a maximum layer thickness of 50µm was observed.

RCF cracks like squats have in many cases been found to be associated with WEL. WEL have in this paper been found to be induced by grinding and to decrease when it is worn off when trains are using the rails.

There might be a connection between the formation of WEL from the grinding process and the comprehensive problems with RCF cracks in Denmark in especially the more wear resistant head hardened rail steel R350HT, where initiated cracks have more time to grow and therefore are not worn away. However a systematic investigation of the effect of grinding parameters on the temperature increase, cooling speed, retained austenite and residual stress is needed to investigate whether or not the grinding induced WEL are coupled to the initiation and propagation of RCF cracks.

REFERENCES

- Boothroyd G., 1975. Fundamentals of metal machining and machine tools. McGraw-Hill, p. 57.
- Buono V.T.L., Gonzalez B.M., Lima T.M., Andrade M.S., 1997. Measurement of fine pearlite interlamellar spacing by atomic force microscopy. *J. Mater. Sci.* 32, 1005-8.
- Carroll R.I. and Beynon J.H., 2007. "Rolling contact fatigue of white etching layer: Part 1 Crack morphology", *Wear* 262 1253-1266.
- Danoix F., Julien D., Sauvage X., Copreaux J., 1998. Direct evidence of cementite dissolution in drawn pearlitic steels observed by tomographic atom probe. *Mater. Sci. Eng. A* 250, 8-13.
- Darken L.S. and Gurry R.W., 1953. Physical chemistry of metals. McGraw-Hill.
- Feller H.G., Walf K., 1991. "Surface analysis of corrugated rail treads", *Wear* 144 153-161.
- Gensamer M., Pearsall E.B., Pellini W.S., Low J.R., 1942. The tensile properties of pearlite, bainite and spheroidite. *Trans. ASM.* 30, 983-1019.
- Griffiths B.J., 1987. Mechanisms of white layer generation with reference to machining and deformation processes. *J. Tribol.* 109, 525-30.
- Hosseini S.B., 2013. Characterization of white layers induced by hard turning of AISI 52100 steel. Chalmers Univ. Technol, Gothenburg.
- Zhang H.W., Ohsaki S., Mitao S., Ohnuma M., Hono K.; Microstructural investigation of white etching layer on pearlite steel rail, *Mat. Sci. Eng. A*, Vol. 421, Issues 1–2 (2006) 191–199
- Zhang X., Godfrey A., Hansen N., Huang X., 2013. Hierarchical structures in cold-drawn pearlitic steel wire. *Acta Mater.* 61, 4898-909.
- Zhang X., Godfrey A., Huang X., Hansen N., Liu Q., 2011. Microstructure and strengthening mechanisms in cold-drawn pearlitic steel wire. *Acta Mater.* 59, 3422-30.
- Zhang X., Hansen N., Godfrey A., Huang X., 2014. Hierarchical structures and strength in cold-drawn pearlitic steel wire. In: Proceedings of the 35th Risø international symposium on materials science: new frontiers of nanometals. Risø, Denmark: DTU.